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**DEVELOPMENT AND TESTING OF A  
NETWORK-CENTRIC, MULTI-UAV  
COMMAND AND CONTROL  
SCHEME USING A VARIABLE  
AUTONOMY CONTROL SYSTEM  
(VACS)**

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**OCTOBER 2003**

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<b>14. ABSTRACT</b> A simplified command and control scheme was developed to reduce the cost and complexity of managing and controlling UAVs using a Variable Autonomy Control System (VACS). VACS allows for autonomous route following capability while allowing dynamic real-time control to deviate from pre-planned routes. This degree of flexibility permits the accomplishment of a wide variety of tasks, while reducing human workload requirements significantly below that of existing UAV systems. A network-centric approach to communications facilitates simultaneous control of multiple UAVs from a single command and control station. The network-centric command and control scheme allows a single operator to effectively manage and employ multiple vehicles, as opposed to multiple operators per vehicle, thus reducing the need for large amounts of equipment and personnel. Furthermore, the VACS design facilitates manned and unmanned systems interoperability. This paper describes the system's architecture and design, as well as the system's capabilities, which were evaluated recently in a series of flight demonstrations.						
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# **Development and Testing of a Network-Centric, Multi-UAV Command and Control Scheme using a Variable Autonomy Control System (VACS)**

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## **Abstract**

A simplified command and control scheme was developed to reduce the cost and complexity of managing and controlling UAVs using a Variable Autonomy Control System (VACS). VACS allows for autonomous route following capability while allowing dynamic real-time control to deviate from pre-planned routes. This degree of flexibility permits the accomplishment of a wide variety of tasks, while reducing human workload requirements significantly below that of existing UAV systems. A network-centric approach to communications facilitates simultaneous control of multiple UAVs from a single command and control station.

The network-centric command and control scheme allows a single operator to effectively manage and employ multiple vehicles, as opposed to multiple operators per vehicle, thus reducing the need for large amounts of equipment and personnel. Furthermore, the VACS design facilitates manned and unmanned systems interoperability. This paper describes the system's architecture and design, as well as the system's capabilities, which were evaluated recently in a series of flight demonstrations.

## **Background**

The recent conflicts in Afghanistan and Iraq have clearly showcased and proven the role

of UAVs in modern warfare. As that role continues to expand, further increases in UAV capability and effectiveness are necessary to cope with an increasingly more challenging battlespace. The increasing level of sophistication in UAVs capability calls for improved ways to manage and utilize these assets. Increasing the level of UAV autonomy is one possible way to reduce the cost and complexity of managing and controlling UAVs. The employment of networked command and control ( $C^2$ ) functions is also an important element for increasing the capability for cooperative/coordinated actions among elements in a constellation of combat assets.



Fig. 1 - Constellation of assets in a network-centric battlespace.

The events in the recent Iraqi war clearly show how quickly war plans can change. To cope with such situations, both the  $C^2$  system, as well as the execution element, must have dynamic re-tasking capabilities. The dynamic re-tasking capabilities facilitate the assignment of resources for a better match between emerging threats and a corresponding ISR/neutralizing resource. A network based  $C^2$  approach can be an essential element to aid in the execution of more efficient CONOPS under rapidly changing scenarios (i.e. the ability to assign the correct asset for the correct task, at the correct time from a “pool” of interconnected resources.)

This “network” acts as an airborne tactical internet of sorts that brings together ISR/Attack/  $C^2$  assets, providing a high degree of flexibility to deal with a variety of threats. The ability to conduct UAVs operations in a cooperative/coordinated mode also has significant implications in vehicle design. By placing increased

emphasis and reliance on the synergistic effect of combining capabilities of multiple vehicles via network-centric operations, it is possible to relax individual vehicle design requirements, which translates into smaller payloads, and smaller demands on onboard power systems. Thus, to realize the full potential of UAVs, the guidance and control technologies implemented must provide the aforementioned level of flexibility. These technologies in turn must increase the UAV system autonomy to levels that enable one or few potentially non-rated operator(s) to effectively manage and control multiple vehicles and their payloads from varying command and control locations and platforms.

#### **VACS as a Command & Control Element**

The VACS was originally designed as a simplified user interface and control system for UAVs (Ref. 1) that would increase the UAV's effectiveness potential. The goal was to produce a novel autonomous & semi-

autonomous flight and sensor controls system with "point-and-click" functionality designed for both independent and coordinated dynamic control of UAV and payload/sensor, that would also simplify the management and control of UAV assets in general. It accomplished this by approaching the  $C^2$  problem from a different perspective – "fly the UAV as a missile" and design to human factors. The resulting system gives the user real-time interactivity with the vehicle, libraries of pre-programmed maneuvers/modes and air traffic control vectoring functionality that simplify the  $C^2$  duties of the operator. Although the user is still capable of interacting via "stick and rudder" type inputs, the operator typically deals with higher level "point and click" commands that enable him/her to focus on mission management as opposed to flying the vehicle. Thus manpower and training/qualification requirements are reduced significantly. Using commercial

off-the-shelf (COTS) products, the system's associated ground control equipment (laptop type computer + transceiver equipment) is relatively small, thus offering a small logistics footprint that allows for a large degree of portability.

Despite a small footprint, the C<sup>2</sup> capabilities are comprehensive since the design focused on mission controller needs, with consideration to current CONOP concerns (Fig. 2)

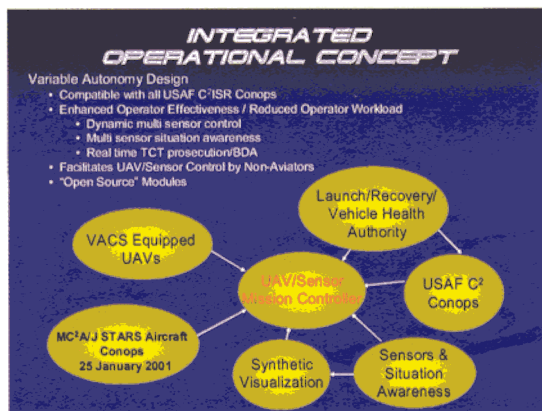


Fig. 2 – Operational concepts incorporated into the VACS design.

The system was also designed with a highly scaleable and modular architecture. facilitates the addition and expansion of capabilities (Fig. 3)

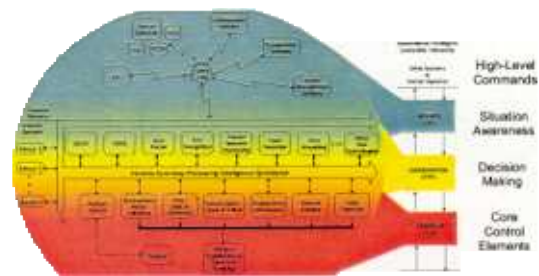


Fig. 3 – VACS Architecture

VACS also offers the capability of transferring C<sup>2</sup> functions between stations. This capability introduces a great degree of flexibility to conduct operations from the best suited C<sup>2</sup> post at a given time. After coordination for control of a networked asset, C<sup>2</sup> authority is transferred from one station to another. This capability enables controlling UAV assets from other manned airborne C<sup>2</sup> aircraft (Fig. 4).



Fig. 4 - Manned airborne C<sup>2</sup> assets controlling multiple UAVs.

Being able to control UAVs from other airborne command posts enhances the effectiveness of assets such as JSTARS, AWACS, etc., by enabling coverage of areas otherwise obscured or out of reach by the C<sup>2</sup> platform itself (Fig. 5). This capability was demonstrated in Sept. 01 during an exercise at Ft. Drum, NY thru interaction with a simulated airborne C<sup>2</sup> post.

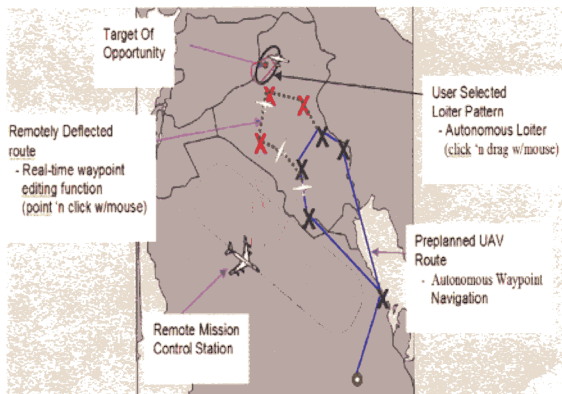


Fig. 5 – Wide area surveillance scenario.

To address the interactivity and control of multiple vehicles, a network-centric approach to communications was adopted. Thru linking elements in a network, each ISR UAV asset becomes a “server” from which the controller obtains real-time information. This level of connectivity between ISR assets and the warfighters enhances overall situational awareness and effectiveness of all participants (Fig. 6).



Fig. 6 - UAV assets operating in a network-centric warfare environment.

The VACS multi-vehicle control capability was demonstrated in a Jan 03 exercise at Desert Center, CA. The exercise involved simultaneous control of multiple UAVs (3) in a coordinated mission scenario under the control of a single operator (Fig. 7).



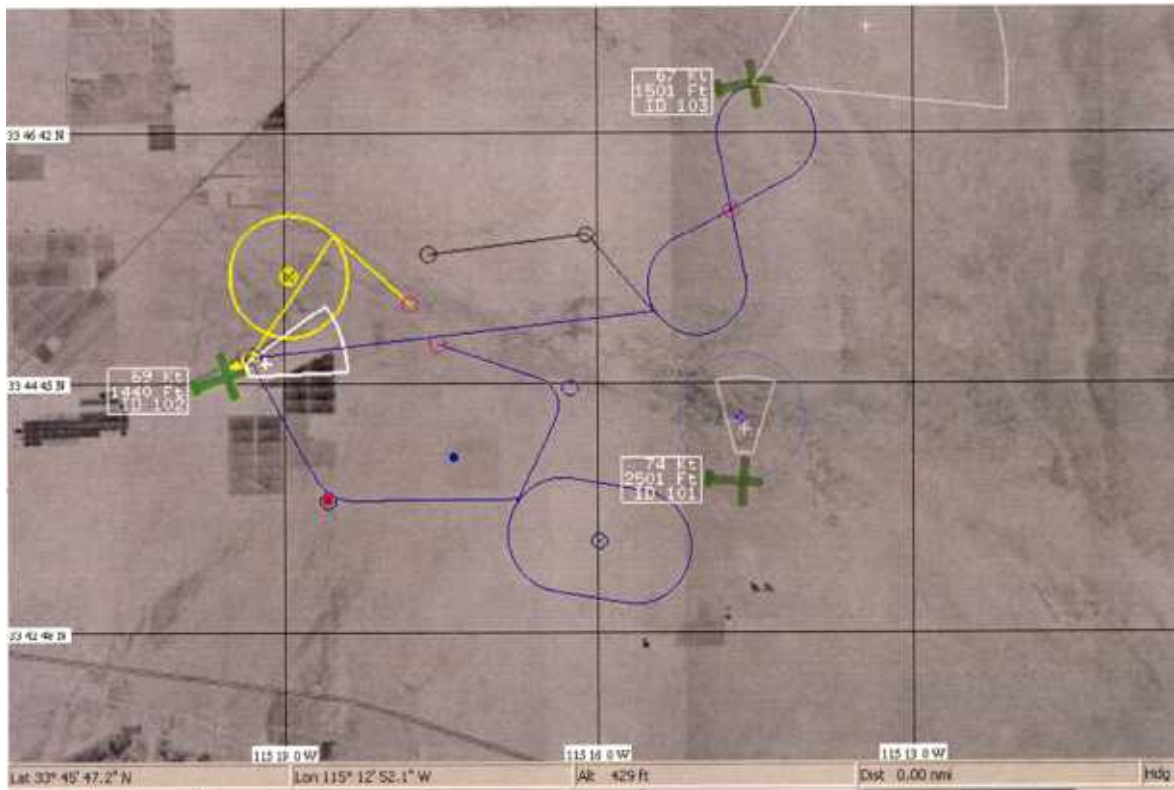


Fig. 7 – VACS Multi-UAV exercise scenario.

The baseline capability of controlling multiple networked, similarly equipped assets also opens the door to cooperative engagement scenarios, where a single battle manager controls the combined resources from multiple vehicles in a "cooperative" or "swarm" attack whether using electronic means or conventional munitions.

As indicated previously, the simple user interface in VACS facilitates a significant amount of control from few, if not a single operator. As the functional capabilities of intelligent software mission control agents increase, more autonomy can be delegated to the vehicle's control system thus allowing the operator to concentrate on higher level mission details. Eventually, the level of sophistication will enable control not only



from dedicated mission controllers, but from pilots in their cockpits.

## **Conclusion**

The Variable Autonomy control System (VACS), combined with network-centric communications capability, is a comprehensive, flight proven air vehicle multi-modal management and control architecture designed to support the emerging generation of autonomous and semi-autonomous UAV systems. The synergistic combination of advanced control concepts, intuitive human-system interfaces, and photo-realistic synthetic vision displays offers a comprehensive, off-the-shelf multi-UAV management and control package. VACS provides a core flight control architecture that will enable the rapid transition of autonomous UAV technologies to the war fighting community.

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